

THE DRINKING STIMULUS AND RATE OF WATER PASSAGE  
FROM THE STOMACH TO THE INTESTINE

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FACILITY FORM 602	N 65-35780	
	(ACCESSION NUMBER)	(THRU)
	9 (PAGES)	1 (CODE)
	(NASA CR OR TMX OR AD NUMBER)	04 (CATEGORY)

Translation of "Pit'yevoye vozbuzhdeniye  
i skorost' perekhoda vody iz zheludka v kishechnik."  
Doklady Akademii Nauk SSSR, Vol. 159  
No. 5, pp. 1194-1196, 1964

GPO PRICE \$ \_\_\_\_\_

CSFTI PRICE(S) \$ \_\_\_\_\_

Hard copy (HC) 1.00Microfiche (MF) .50

ff 653 July 65

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(Presented by Academician V. N. Chernigovskiy 10 August 1964)

## ABSTRACT

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Evidence is presented in support of a gastric emptying mechanism whereby regulation of the fluid flow from the stomach into the duodenal is realized by virtue of centralized nervous activities, tentative forms of which might be internal temperature, hormonal activity, or variations in the stimulus level of the drinking center. A further indication is that the stomach acts as a reservoir, metering fluids into the organism's interior medium depending on current need. The dependence of gastric emptying on thirst is determined, using "imaginary drinking" experiments and isolating the resultant effects from stimulation of the mucilagenous portion of the duodenum.

*Author*

## INTRODUCTION

It had already been established by the end of the last century that the 1194 apportioned transfer of food from the stomach into the intestine depends on the stimulation of receptors in the upper intestinal tract due to contraction of the pyloric sphincter (cited from ref. 1). Later, in the laboratory of I. P. Pavlov, the problems of chemical effects on the gastric emptying activity in connection with the stimulation of the duodenal chemoreceptors were investigated

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in detail (refs. 3 to 5 and 9). It would be impossible within the scope of the present paper to review in a comprehensive manner the literature devoted to this problem. We merely note that the majority of contemporary researches assume that evacuation of the gastric contents is regulated preponderantly, not by the kinetics of the pyloric sphincter, but by the motor activity of the entire stomach (see the review in ref. 11). In the opinion of one of the most authoritative researchers in this problem, J. N. Hunt (ref. 10), the level of gastric emptying activity is regulated by variations in the stroke volume of the antroduodenal pump and powerful pressures exerted by the osmoreceptors of the duodenum. In this case, those fluids which are neutral in the chemical sense, vacate the stomach without inhibition and at a constant rate. It is assumed, therefore, that the passage of fluids from the stomach into the intestine is governed exclusively by their osmotic concentration, which is not regulated in the stomach, but in the duodenum. This lends support to Waldeyer's hypothesis (cited in ref. 11) that water rapidly vacates the stomach via a channel formed by the muscles of the greater curvature (the so-called "stomach passage").

We have previously been able to observe that the rate of water evacuation from the stomach is not always stable (ref. 2). Specifically, it is slowed down abruptly after several additions of 300 to 500 ml of 3-5% sodium chloride solution into the stomach cavity, an effect that could be regarded in a number of cases as the onset of a condition reflex. However, this effect could not always be attributed to conditioned reflex factors. The objective of the present study has been to find out whether the rate of water passage into the intestine depends solely on localized gastroduodenal processes or whether it is also associated with some sort of centralized effects. In order to simplify as much as possible the attack on this problem, we began by investigating the rate

of water evacuation from the stomach either in the thirsty state or not in the thirsty state. Moreover, in order to differentiate between effects originating from the gastric receptors and the intestine, we strove to preclude stimulation of the mucilaginous duodenum by water evacuated from the stomach. Logically, we could proceed from two assumptions. The first corresponds to the modern notions of the stomach evacuation mechanism (refs. 10 and 11) and asserts that the passage of water into the intestine is accomplished irrespective of the state of the drinking center. The second assumption admits the possibility of definite influences exerted by the level of excitation of the drinking center on the rate of water evacuation from the stomach.

#### PROCEDURE

Fifty-five experiments were performed on two dogs with preinduced fistulas in the stomach, duodenum (3 cm from the pyloric portion of the stomach and at 1195 the beginning of the jejunum), and bladder. After securing the dogs in the test stand, the fistulas were opened and rubber tubes inserted. During each experiment, three ten-minute samplings were made, one right after the other, to investigate the evacuation of water from the stomach. 100 ml of tap water, heated to a temperature of 38°C, were fed into the stomach directly through the fistula, after which the rubber tube leading from the gastric fistula was clamped off. The rubber hoses inserted into the fistulous tubes of the duodenum were lowered into a graduated cylinder, and every 1, 3, 5, 8, and 10 min the quantity of fluid emptied from the stomach was measured. After the expiration of 10 min, water was added to the stomach in an amount commensurate with the volume of fluid that had been drained off during the preceding 10 min from the duodenal fistula. The same procedure was again repeated after the second ten-minute sampling.

The experiments were run against a background of various functional states on the part of the animals; either on the normal feeding schedule with free access to water, or after 18 to 40 hours deprivation of water and xerophagia. The presence or lack of thirst was tested qualitatively at the beginning of the experiment and quantitatively at its termination by measuring the volume of water taken by the dog with the gastric and duodenal fistulas open ("imaginary drinking") or with the fistulas closed ("true drinking").

#### RESULTS

Before comparing the emptying function of the stomach against a background of thirst and in the absence of the drinking stimulus, it must be ascertained how stable and stereotyped this function is under the given experimental conditions. It turned out that the same dog with the same background of drinking stimulation exhibited certain fluctuations in the rate of water evacuation from the stomach from one experiment to the next. These fluctuations, however, were not appreciable or systematic, whereas the differences in water evacuation rate between thirst and nonthirst conditions were quite substantial.

As apparent from figure 1A, the total amount of fluid transferred into the intestine after 10 min was  $18 \pm 5.1$  ml of the 100 ml introduced into the stomach, whereas under thirst conditions this quantity was equal to  $74 \pm 6.2$  ml. Such a marked difference in the mean indications was observed in comparing the evacuation rates during the second and third ten-minute periods ( $27 \pm 6.1$  and  $33 \pm 7.0$  ml in the absence of thirst;  $77 \pm 5.7$  and  $78 \pm 5.0$  ml in the presence of thirst).

The same behavior was observed in the experiments with the second dog (fig. 1B). The mean indications in rate of water evacuation from the stomach into the intestine after three 10-min periods were  $23 \pm 13.0$ ,  $9 \pm 3.5$  and

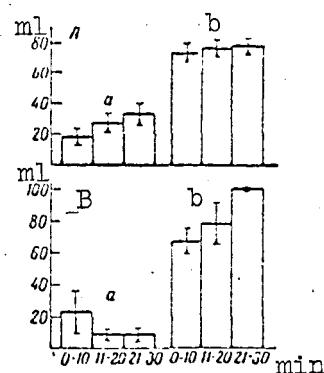


Figure 1. Passage of Water from the Stomach into the Intestine as a Function of the Absence (a) or Presence (b) of Thirst After Three 10-Minute Periods with Two Dogs, Novaya (A) and Alma (B).

9  $\pm$ 4.0 ml in the absence of thirst. In the thirsty state these indications were equal to 67  $\pm$ 7.7, 78  $\pm$ 13.0, and 100 ml, respectively.

The data presented herein lead to the conclusion that the drinking stimulus exerts a stimulating influence on the rate of water passage from the stomach into the intestine. When thirst is absent, water remains in the stomach for a considerably longer time than when the drinking stimulus is active. This may be regarded as a kind of banking system, which enables the organism to defer the intake, into its interior medium, of substances that it does not need at the moment. This point of view is well in accord with the notions of the stomach as the primary nutritive depot (ref. 6).

As already noted above, the passage of water into the intestine is not always accomplished at the same rate, even against a background of the same functional state on the part of the drinking center. This leads us to believe that several centralized factors are operative, affecting the rate of water evacuation from the stomach, factors which have not been taken into account under the given experimental conditions. One might tentatively suggest variations in the overall stimulus level of the animal from one experiment to the

next, excitation of the drinking center, a hormonal background, or temperature of the interior medium as possible factors affecting the emptying capacity of the stomach.

It was also very important to find out whether the rate of water passage into the intestine depends on the functional state of the drinking center or whether it is also related to the degree of hydration of the organism's tissues. This question was resolved in experiments with "imaginary drinking," which, while temporarily relieving thirst, retarded the rate of water evacuation from the stomach. Of course, the dehydration level of the organism in this case was not altered.

The fact that the state of the drinking center is one factor governing the transfer of water from the stomach into the intestine indicates that this center not only provides for behavioral responses directed toward the prevention of dehydration of the organism, ~~it also controls the vegetative responses that~~ maintain fluid homeostasis. The presence of thirst, reflecting the need for water, leads to a rapid intake of water into the intestine, hence into the interior medium. The absence of thirst permits the organism to utilize the stomach as a water depot.

A problem that is yet unclear is what significance local factors have with regard to the rate of water passage. It is known that the stomach receptors play an important part in the kind of events that contribute to the digestive behavior of higher animals (see the review articles in refs. 6 to 8). It must be presumed that the drinking center receives information from the gastroduodenal tract as to the chemical composition of the fluid that it acquires. Since in our experiments we eliminated signalization from the duodenal receptors, it may be assumed that this information was generated due to the action of the stomach

receptors. This assumption is not consistent with the notions of Hunt (ref. 10), who rejects the presence of receptors in the stomach, which affect the evacuation activity. However, we cannot conceive of any other mechanism under the conditions when the stimulant (water) does not get into the intestine. It would be impossible in the present report to discuss in detail the data on the rate of gastric emptying of hypertonic electrolytic solutions. It suffices to note that this rate differs considerably from the rate of gastric emptying of water. Inasmuch as the stimulation of the duodenal receptors is eliminated in this case, we can only surmise that the chemo- and osmoreceptors of the stomach do not remain indifferent with respect to the evacuatory function of the stomach.

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Received 19 July 1964

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Translated for NASA by Stemar Engineering Inc.  
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